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A REVIEW OF
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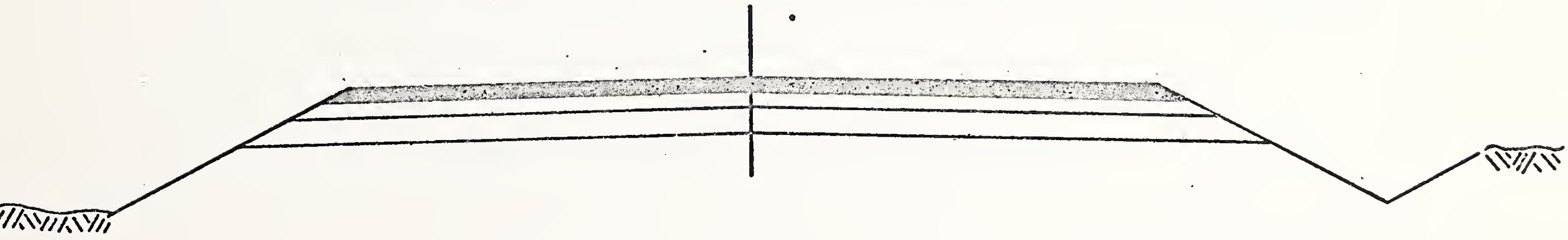

Montana State Highway Department

A REVIEW OF
FLEXIBLE PAVEMENT DESIGN METHODS
AND RELATED PROCEDURES

by

David L. Rydquist, Surfacing Designer

February, 1967

PRECONSTRUCTION DIVISION

MONTANA STATE HIGHWAY DEPARTMENT

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LIST OF EXHIBITS

EXHIBIT NO. DESCRIPTION

1. . . . . Allen Classification of Highway Subgrade Materials

2. . . . . Montana Highway Department Application of the Classifications and Group Index of Subgrade Soils in Estimating Desirable Subbase and Total Pavement Thickness (1947)

3. . . . . Revision of Exhibit No. 2 (1955)

4. . . . . Soil Support Value Conversion Chart

5. . . . . Loadometer Study Wheel Base Factors

6. . . . . Surfacing Coefficients for Pavement Structural Components

7. . . . . Flexible Pavement Design Chart 400-1

8. . . . . Flexible Pavement Design Chart 400-2

9. . . . . Flexible Pavement Design Example

10. . . . . . . Laboratory Form No. 76 for Soil Surveys

11. . . . . . . Wyoming Standard Soil Survey Sheet

12. . . . . . . Comparison of Montana and Arkansas Soil Support Values

13. . . . . . . Memo from B.P.R. on Pavement Design

14. . . . . . . Correlation Chart for Estimating Soil Support Values

15. . . . . . . Idaho Factors for Climatic and Environmental Effects

16. . . . . . . Application to Secure Materials Site

17. . . . . . . Available Surfacing Materials Report

18. . . . . . . B.P.R. Computer Program Data Sheets and Comments

19. . . . . . . California Design Standards for Flexible Pavements

FOREWORD

It was originally intended that this report would simply evaluate the R-value method of evaluating subgrade materials. However, it became apparent to me that the R-value method has not only been evaluated, but tried and proven as a satisfactory design procedure. That the R-value method is a more desirable method than the group index is a fact that is validated by the number of organizations that have initiated the use of the R-value in preference to the group index. The final justification for the adoption of the R-value method in this state should come from a comparison of the two methods in actual use for our own conditions.

As the problems involved with soils were reviewed, it also seemed apparent that this report would provide an opportunity to review the problems of related procedures. As a result, this report resembles an in-depth inspection of the Paving Section's functions and responsibilities. Possible solutions have been presented, but the report does not include any recommendations as I felt a great deal more study and investigation should be devoted to each of the problems before a recommendation is made.

Thus this report is actually a study of study needs. It is my hope that it will help instigate action to further investigate, study, and improve pavement design procedures.

David L. Rydquist

David L. Rydquist

I. INTRODUCTION

The Paving Section of the Montana Highway Department was formally established in 1948. Tom Bogy was named as Paving Engineer, a position which he served until his retirement in June of 1965. During these years the Paving Section was under the direct administration of the Preconstruction Department. After Mr. Bogy's retirement the Paving Section remained in the Preconstruction Division, but was included in the Road Design Department, and the title of Paving Engineer changed to Surfacing Designer.

The primary responsibility of the Paving Section is the design of surfacing depths for all roadway projects in the State. Inasmuch as at least 95 percent of all paved roadways have been of an asphalt type surface, flexible design has been the main function. In recent years as traffic has increased and construction methods have improved, the feasibility of rigid pavements has become a reality. It is now standard procedure to prepare detailed analysis and comparison for the two types of pavement on most projects. The large majority of designs still favor the flexible type and for that reason this report is concerned mainly with flexible pavement design.

The other functions and responsibilities of the Paving Section are all related to surfacing design or material. Of most significance is the processing of gravel sources. The location, ownerhsip, quality, quantity, and availability of surfacing materials is information that must be obtained from the field and furnished to the contractor prior to the letting of a contract. A complete file of all gravel sources sampled, as well as a file that contains all projects let since 1948 with surfacing and applicable data for the surfacing, is kept in the Paving Section office.

The purpose of this report is to review the methods and procedures involved in accomplishing the primary functions of the Paving Section. Experience has indicated that present methods are not entirely satisfactory and it is intended that improved methods be reviewed, analyzed, and suggested for consideration.

II FLEXIBLE PAVEMENT DESIGN

The history of the design of surfacing structures in the Montana Highway Department can be limited to the past twenty years. Prior to 1947 the principal factors involved in determining the depth of typical sections were previous experience and personal judgment. Soil surveys were conducted as early as 1935, but what method of classifying the soils and how that data may have been applied is not clearly understood.

In 1945 the Highway Research Board, AASHO, and the Bureau of Public Roads adopted a classification of highway subgrade materials known as the "Allen Classification"(1) (See Exhibit No. 1). The Montana Highway Department adopted the "Allen Classification" shortly thereafter and in 1947 a chart was developed for estimating pavement thickness on the basis of subgrade soil classification (See Exhibit No. 2). This was the department's first formal attempt at correlating soil types with pavement thicknesses, and was intended as a guide to be supplemented by previous experience and personal judgment.

Use of the above chart and policies continued until 1955 when it was revised to a more refined version (See Exhibit No. 3), but the basic policy remained the same. In the next few years, more and more reliable data and tests became available showing that accurate evaluation of the factors involved provided valuable tools for the design of flexible pavements. One of the most widely publicized and acknowledged sources of such information was the AASHO Road Test which was completed in 1960. In 1961 a guide to flexible pavement design was published by AASHO(2) which was based on the AASHO Road Test Data, supplemented by data developed from practices already in use by construction agencies. The Bureau of Public Roads adopted the

guide and requested the state to revise design methods so that reasonable conformity or correlation to the guide was evident. Mr. Bogy began initiating procedures in 1962 and by 1964 had developed the procedure that with minor alterations is still being used at the present.

The design procedure as shown in the guide requires the assembly, evaluation, and correlation of a number of factors. The following review of those factors and how they are presently evaluated will provide a brief summary of present procedures.

1.) The character and type of soil upon which the roadway structure will be placed. For the evaluation of the subgrade soil the use of the Allen Classification and Group Index method was continued. However, it was necessary to develop a chart which could be used to convert the soil classification to a "Soil Support Value". Such a chart was devised (See Exhibit No. 4), in 1962 and is still in use at the present.

2.) The volume and weight of the traffic that will be carried. Prior to 1961 the volume of traffic received consideration, but not the weight. From the AASHO and other road tests it became apparent that the critical volumes were the vehicles with heavier loads. For accurate design it was desirable to know not only the volume of trucks, but also the approximate loads that could be expected for the surfacing structure to support. To obtain this data the Planning Survey Division initiated an annual study that would determine wheel load factors that could be applied to volumes of trucks on various types of roadways. The study has been conducted for the past three years and the factors now in use are based on these studies$_{(3)}$ (See Exhibit No. 5). These factors enable us to compute "Equivalent 18 Kip Single Axle Wheel loads per day" for all types of traffic and roadways.

3.) The suitability and quality of materials available to build the structure, including their relative ability to support loads when incorporated into the structure. In other words, it was necessary to develop a table of relative values that would show the comparable ability of various surfacing materials to support loads. On the basis of the data derived from the AASHO Road Test and correlating information from other states, a table of surfacing coefficients was developed and adopted. The coefficients being used at present have undergone recent revision (See Exhibit No. 6), but are very similar to those originally proposed by Mr. Bogy.

4.) The environmental conditions under which the structure will serve. Climactic and environmental conditions are quire varied throughout this country and some consideration for these differences should be reflected in the structure of a pavement. The guide(2) outlined a procedure by which a regional factor may be obtained for an area. It was expected that values between 0.5 and 3.0 would cover environmental conditions within the United States. For Montana, a value of 2.5 was derived which is used for the entire state.

5.) The type and quality of service expected from the pavement structure during its anticipated life. In one word, Serviceability, is the key to the AASHO guide design procedure. The massive data from the road test gave the basis for the "Road Test Equation" which amounts to "a function of the ratio of loss in serviceability a time "t" to the total potential loss taken to the point where the serviceability equals 1.5 (the point at which the road test sections were removed)". The equation is presented graphically in the form of nomographs for serviceability levels of 2.0 and 2.5 with a traffic analysis period of 20 years (See Exhibits No. 7 & 8). Application of the previous criteria to these charts shows the re-

quired structural strength for a roadway section. Economics and special environmental situations are important factors that help determine the final design. Exhibit No. 9 is an example showing the application of the preceding factors in a sample design problem.

Of the five factors previously mentioned there are two which warrant further discussion - soils and the environmental conditions. Our evaluation and application of the other three factors are generally comparable to procedures of other organizations that have had the time and facilities to prove them. In the case of soils and environmental conditions there does appear to be a need for further investigation and possible change of our present methods.

III. THE SOIL SURVEY

The soils data is without question the most important factor in surfacing design. It is also the most frequent source of problems in the Paving Section which causes ultimate delay of a project. A variety of conditions exist that create such situations varying from the reporting procedures to the analysis of the soil support value.

1. Reporting the Soil Survey.

The sampling procedure employed on projects is presently a procedure that varies in every district according to available equipment, personnel, and equipment. Generally, the soil survey is conducted as soon as the hopefully final alignment is staked out. It is at this point that the soil survey problems begin. In some cases the field soils man is not informed of the probable grade line or if he does know the grade line he doesn't have equipment capable of securing appropriate samples, such as in a 50'± cut. The general result in these cases is that the Paving Section requests additional soils data to be obtained by either the division of Helena Lab Crew. The additional time required to complete the soil survey can be quite costly as under the present policy the amount of progress that can be made in the design of a project without typical sections is quite limited. To illustrate the preceding point, the case history of an actual project shows a typical example of what can and does occur.

The location and soil survey on the project had been completed and sent to the Road Design Section, who requested a typical section from the Paving Section. Upon reviewing the soil survey and a probable grade line obtained from an Assistant Road Design Engineer, it was obviously apparent that additional soils data was necessary for pavement design. The probable

grade line and request for additional soils data was sent to the field in February. The Preconstruction Division wanted to continue work on the project and were planning to obtain approval of interchange locations from the Bureau of Public Roads. For such, a layout of the interchange from the Traffic Section was necessary. However, Traffic could not draw up a layout until they received a grade from Road Design, and Road Design could not establish a grade until they received the typical sections, which could not be designed until the additional soils data was received. The soils data arrived in May, at which time work on the project continued, but the fact remains that virtually all work on the project was halted because of a soil survey.

The above instance is typical of a number of projects that have been delayed for lack of soils information. Sometimes it is because no soils survey has been done at all, as the construction season is placing increasingly heavy loads on the field materials personnel and they don't have the time, equipment, or men available for preconstruction work until winter shutdown. The occurrence of such delays happens frequently enough to indicate that some revision of present practices may be desirable.

The form on which the soil survey is reported is a starting point for revision. The present "Lab. Form No. 76" (See Exhibit No. 10) has been criticized by both the field and Bureau of Public Roads as being inadequate. A much more desirable form would be one similar to that used by the State of Wyoming, (See Exhibit No. 11) which contains the profile, grade, sample locations, and test results on the same sheet. Some extra work would be involved in plotting the profile and grade on such a form and it would be necessary to determine who should perform the duty and when it should be done. Under present policy there would be some definite obstacles to over-

come as presently the grade cannot be determined until the soil survey has been received as was illustrated in the preceding example case. As an answer to the question of timing,the following procedure is proposed as a possible solution.

A. After the alignment has been chosen and the location survey completed the field soils man will make a preliminary survey that should resemble a geological report denoting the general characteristics of the project, special features such as sloughs or swamps that may seriously affect the grade, and past experience with roadways in the area, if any. This information will be forwarded to the Preconstruction Division in Helena.

B. On the basis of the preliminary soil survey, the paving section will design a preliminary typical section and submit it to the Road Design Section.

C. Road Design will then develop a probable grade line and compute approximate earthwork quantities. The profile, grade, and quantities will be plotted on the revised soil survey sheets and sent to the field with a request for final soils survey.

D. The field will complete the final soil survey and send the results to Preconstruction. The Paving Section determines the final pavement design and sends it to Road Design for final design of the project. The Paving Section would also send copies of data, computations, comparisons, and recommendations for the final section to the Bureau of Public Roads for concurrence.

The actual application of the above proposed procedure would require a great amount of cooperation and understanding among all concerned before it would work effectively. Undoubtedly there exist obstacles which cannot be forseen at this time. However, in view of the problems being experienced

at the present, the suggested approach may be at least a feasible guide.

2. Evaluation of the Soil Survey.

As was mentioned earlier in the report, the present method of evaluating subgrade soils is by the "Allen Classification" with the group index which is converted to a "soil support value" by means of a chart developed by Mr. Bogy (See Exhibits No. 1 & 4). A recent study conducted by the University of Arkansas,$_{(4)}$ showed a curve developed to obtain soil support values for group indexes. By plotting points from Mr. Bogy's chart on their graph it can be seen that the correlation between their values and ours is very good (See Exhibit No. 12). However, a very important fact that should be pointed out is that the curve developed in Arkansas is only a temporary measure to be employed until the State can obtain facilities for R-value evaluation of subgrade soils.

The Bureau of Public Roads has requested that we consider revising our methods of evaluating subgrade soils (See Exhibit No. 13). Their main cause for concern stems from the results of the AASHO Road Test which showed poor correlation to soil support values determined by the group index method (See Exhibit No. 14). Our own experience with the group index method has convinced the Paving Section that new methods developed and proven in the past two decades have outdated the group index method. A typical example of the limitations of the group index is illustrated in an A-2-4 Soil which will always have a group index of zero. From our soil support value chart (Exhibit No. 4), it can be seen that the soil support value for an A-2-4 soil can vary from 3.0 to 4.5 which is a significant difference yet an entirely possible situation. With this large a range of values for one soil type, a project could actually be under or over designed in an amount up to six inches of gravel base. The additional refinement of a soil within its

classification becomes a matter of personal judgment that has in several instances become a point of controversy. That there are now satisfactory test methods available that would eliminate the majority of the indecisiveness evident in the group index method appears to be an accepted fact.

The tests which have been referred to that provide a more accurate basis for surfacing design are the:

(1) California Bearing Ratio

(2) Plate Bearing Value

(3) Resistance value with Hveem Stabilometer or Triaxial Compression

Of the above three, the Resistance or R-value test seems to be the most popular. In the Western States it is known that Washington, Oregon, California, Idaho, Arizona, Wyoming, Colorado, and the Bureau of Public Roads use the R-value method, the majority of them with the Hveem Stabilometer, and there are very probably others which we haven't heard about. In view of the satisfactory results that other organizations have experienced with the R-value via the Hveem Stabilometer, and the fact that our lab already has some of the necessary equipment (including the Hveem Stabilometer), it is felt that this procedure would be a logical choice here in Montana.

The R-value method of design was introduced in 1948 by Francis Hveem and R. H. Carmany of the California Highway Department$_{(5)}$. It was the contention of these gentlemen that their procedure had overcome the major obstacle in testing soils - measuring the fundamental properties of a soil that would give a true indication of its supporting capabilities in a subgrade. Their theory was put into practice and as performance data became available from their own and other road tests they found they found that minor adjustments were necessary, but in general that the procedure was very satisfactory. In comparing their procedure to the one recommended by AASHO

from the results of the AASHO Road Test, Mr. Hveem reported a correlation coefficient of 0.98, but maintained that the California was a much better procedure(6). In the meanwhile, the organizations previously mentioned as well as several others developed their own R-value procedures, many of them being very similar to California's.

The R or Resistance value is the result of a test which measures two things: (1) The ability of a soil to resist lateral flow due to vertically applied loads. From this value the amount of cover or surfacing required to prevent plastic deformation of the subgrade soil under the expected wheel loads can be determined. This is knownas the exudation R-value. (2) The expansion characteristics of a soil in order that the thickness or weight of surfacing required to maintain compaction of the soil at any moisture content may be determined. This is known as the expansion R-value. Whichever of the two preceding values requires the thickest section is the design R-value.

The actual procedure and equipment involved in the R-value determination is too lengthy to present in this report. An excellent explanation is outlined in an Asphalt Institute publication(7). If the R-value method were adopted in Montana, it would require a great deal more investigation and research before it could be put into use. Although the basic principles remain the same, various organizations have various methods of obtaining the R-value and applying the data to design procedure. Additional investigation and study would be required to determine which way would be the most appropriate for our conditions.

There do exist some obvious obstacles to the adoption of the R-value method. Presumable the Helena Laboratory would assume responsibility for the R-value test program and at the present they do not have adequate room

for their present operation and it would undoubtedly be necessary to secure additional space for the R-value procedure. The Lab does have equipment to run an R-value test, but for an accelerated program there would have to be a considerable amount of additional equipment obtained. A rough estimate of the required expenditure is $20,000 minimum. It would also be necessary to hire and train two technicians to run the R-value tests, and it is probable that they would have little time available for any other duties. A program would have to be started to educate the field personnel about the R-value procedure, as it will be their responsibility to send appropriate samples to the Helena Lab for testing. It is not intended that the group index method be eliminated, as this data will continue to be a useful guide in design, and it will function as a useful guide to the field men for determining appropriate samples for R-value tests. There are undoubtedly many other problems that will arise from the adoption of the R-value procedure that are not obviously evident at this time. Additional study, investigation, and cooperation of the personnel involved will bring to light these problems and their solutions.

3. The Special Soils Condition.

To be sure, the subgrade soils will never be the same for any two projects which in a sense makes every soil survey special. There do exist however, environmental conditions that when present may create a situation that does not necessarily restrict the resulting problem to one project. When such conditions occur, the normal design procedure will not always provide a section that will be adequate and special measures are necessary.

For example, the problem of frost action is one that occurs frequently in many areas of the state. The AASHO Guide$_{(2)}$ states: "The use of a regional factor and the design procedure outlined in this guide will not

adjust for serious frost heaves. It is expected these will be controlled by removal of frost-susceptible materials, by provision for adequate drainage, or by other locally developed procedures." The part about locally developed procedures is the area in which we are in need of improvement.

In the case of frost action, it is usually known by previous experience that such a problem exists and that special treatment will be required. The soils men generally indicate such and recommend a special treatment on the soils survey. The fact that frost action occurred previously is important, but it is not enough in itself to justify the special treatment. Various organizations and notably the Corps of Engineers(8) have developed procedures by which a frost condition can be analyzed and the required treatment determined. If such a procedure was adopted by this organization and was made available to the field men, they would be able to secure the necessary data and submit it with the soil survey. It would then be possible to justify the special treatment before the project is entirely designed and would eliminate the reoccurrence of some costly delays that have happened in the past.

There are other conditions that do not occur as frequently as the frost action problem, but nevertheless could be treated in a similar way. Probably the most effective way tobe sure of informing the field personnel of what data is necessary for a certain situation would be by distributing a manual that would not only explain the special situation, but the normal surfacing design procedure. At the moment it is doubtful that even one field soils man clearly understands how typical sections are designed. If they were informed of such procedures many of the problems we experience would be solved as a matter of course.

IV THE REGIONAL FACTOR

In Chapter II, it was stated that a regional factor of 2.5 had been adopted for the entire state of Montana. To say that the climatic conditions for the entire state are uniform is an undeniably false statement, yet by using a constant factor we are implying that it is true. Our neighboring state of Idaho and probably several others have compensated for this irregularity by dividing their state into regions similar to a railfall intensity map(9) (See Exhibit No. 15). The data for developing a similar map for the State of Montana is a matter of record which can be obtained from the Weather Bureau. The Paving Section itself has an excellent file of climatological data that may have adequate information.

If such a chart were developed it would narrow the margin for error and controversy in surfacing design to some degree. It would also probably provide useful data for the justification of sections with frost action problems. The only foreseeable obstacle to developing such a chart would be to find the time to analyze and evalutate the massive amount of weather data available. Application of the computer facilities would reduce the work involved, but additional help would be needed for coding the data.

V. SURFACING MATERIALS

1.) Exploration and Reporting

Aggregate for surfacing materials is becoming an increasingly important factor in the surfacing design procedure. The value of gravel has increased significantly in the past ten years as resources have been depleted and the law of supply and demand has taken its measure. As a result of this increased value it has become necessary to analyze a surfacing design not only structurally but economically as well.

The use of stabilized bases has become an important factor in surfacing design as they have made it possible to design a satisfactory structure with less material or to use poorer quality materials that were not considered satisfactory prior to the addition of a stabilization agent. On the majority of projects it is obviously desirable that the location,quantity, and quality of gravel sources be known as soon as possible in order that an accurate economic analysis can be made. For the ideal situation the gravel exploration and testing should be completed and available to the Paving Section when the surfacing section is to be designed. For the majority of the projects being designed at the present the gravel sources are received long after the surfacing design has been accomplished.

There are other reasons why it would be desirable to receive the gravel sources at an earlier date. It is very much to the State's benefit to purchase or option gravel sources whenever possible as considerable savings are reflected in lower bid prices when the gravel is furnished to the contractor at no cost. The Paving Section is responsible for initiating proceedings to secure surfacing material sites and perform such by sending our an "Application to Secure Material Site" or "Pink Sheet" (See Exhibit

No. 16). As landowners are becoming more cognizant of the value of gravel, the importance of beginning negotiations as early as possible is becoming more critical as in many cases a period of several months or more is required to negotiate an agreement.

It is also the responsibility of the Paving Section to prepare an analysis of the available sources for the bidding contractors. The gravel tests results and other significant data are compiled on an "Available Surfacing Material Report" (See Exhibit No. 17) for distribution to the bidders. It is very important that all significant data, including the option status, be available in time to prepare the reports and have them printed at least a month before the letting date. There have been frequent cases in the past and present where all the data was not available and either the letting date for the project was postponed or incomplete reports were furnished. Either of the preceding actions is undesirable, and could be avoided if gravel exploration had been completed at an earlier date.

It is realized that there are and always will be occasional circumstances that will cause unavoidable delays in reporting gravel sources. However, it does seem that many of the circumstances that are causing delays at the present could be eliminated if the field forces were informed of the importance of reporting sources sooner and were given some concrete guidelines that would clearly explain when "sooner" is for a project. The manual proposed in Chapter III on soil surveys and surfacing design would be an excellent place to include the significance of early gravel exploration and reporting.

2.) The Gravel Files

The Paving Section maintains the most complete file on gravel sources in the state. It is estimated that about 10,000 gravel sources which have

been explored and prospected during the past forty years are contained in these files. The data in these files is very useful for locating sources, noting the characteristics of gravel in a certain area, or other pertinent facts. Unfortunately, the value and significance of this massive amount of data cannot be truly analyzed and used to its full capacity because it is not organized in an appropriate system. To find, record, and analyze the desired information with the present arrangement is a time-consuming and inefficient operation.

The facilities of the computer section are the logical method of handling this quantity of data. The Bureau of Public Roads is using a program with their computers that is similar to what is needed here (See Exhibit No. 18). Considerable time and study would be necessary for the development of a program satisfactory to our needs, and additional help would be required for the enormous chore of coding the volumes of existing data. Once these original obstacles have been overcome it would require little effort to keep the data current. The efficiency and analytical capabilities of such a program when in operation would be a valuable tool for surfacing design and of significant benefit to the organization.

Although there is a vast amount of data available on gravel sources there is always room for more. The characteristics and behavior of aggregate after production is important data that at the moment is being somewhat overlooked. Project engineers at the present do send in depletion reports on gravel sources showing quantities removed and remaining and also the actual weight of the final product per cubic yard. These reports could easily be supplemented with remarks concerning any particular difficulties in the production or processing of a gravel course. This data in turn could be put into the computer for reference or analysis. To obtain the desired informa-

tion a depletion report form could be devised that would clearly show the project engineer what data is desirable. The information could then be easily coded for use in the computer and would thus be available for a variety of functions.

VI MISCELLANEOUS NEEDS

1. Minimum Surfacing Depths

Once in a while the conditions of light traffic and excellent subgrade soil occurs and it becomes apparent that a minimum depth of surfacing is required. Just what the minimum depth should be is a matter on which there has been no established policy in the past or present. The "opinion" method now employed is subject to controversy and delay that could be avoided if a policy was adopted and incorporated into the standards.

2. Plant Mix Thickness

Presently there exists an unwritten policy concerning the depth of plant mix on roadways which is as follows:

a)	Secondary Highways	0.20' Type a Plant Mix with a seal & cover application
b)	Primary Highways	0.25' Type 3 Plant Mix
c)	Interstate Highways	0.35' Type 3 Plant Mix

In the case of the Interstate highways the 0.35 ft. is a national standard to which we must conform. However, for the Secondary and Primary highways the justifiable facts and reasoning for the selection of such depths are not readily apparent.

It would seem logical that the depth and type of plant mix used on a highway should be a direct function of the expected volume of traffic, regardless of how the route is designated. If this theory were applied it is likely that the majority of the projects designed would have the same wearing course as present policy would call for. There does exist however, the occasional case where a Secondary road receives more traffic than most Primaries, or a Primary receives more traffic than a heavily traveled Inter-

state, or a Primary that receives less traffic than many Secondary roads. For these cases at the present there is no effective means of justifying additional or less wearing course if such were desired. A means could be provided if a table similar to one used by California(10) (See Exhibit No. 19) was developed and included in the design standards.

3. Research and Evaluation

The most critical need for an organized research program for surfacing materials is not in experimenting with new materials but to simply evaluate what we have. No data is more reliable than that which is obtained from a performance in an actual environment. Every project that is constructed is a potential research project, yet at the moment there is not one mile that is being evaluated for performance or analyzed for failure for the purpose of obtaining important data that could prove or disprove the adequacy of surfacing design procedures. In the past few years there have been several projects that have been designed with special features such as sand chokers, bituminous membranes, etc., which had to be justified to the Bureau before they approved the sections. Many of these justifications leaned heavily on theory and research of other organizations as our own did not have reliable data available, which is an acceptable engineering procedure. The fact remains however, that we have not taken advantage of the opportunity to obtain our own reliable data on the performance of the special features once they have been approved. Nor are we retaining the pertinent facts in regard to problems that may have been encountered in construction of the special feature which could also have considerable bearing on the use of the feature for future projects. Furthermore, the benefits that would be derived from the initiation of such a program could be extended to include other departments such as Hydraulics and Road Design.

To establish a program of this sort would require a great deal of planning and effort as it would be a research project in itself just to develop a format and determine the appropriate projects or situations to evaluate. The obvious benefits to the organization from a program of this type appear to make further investigation into its feasibility worth consideration.

VII SUMMARY

This report has outlined possible methods by which the flexible paving design procedures may be improved. It is felt that the following points deserve further attention and study in the interest of developing more efficient, economical, and technical procedures that will benefit the Paving Section and the organization.

1.) Changing the form on which soil surveys are reported.

2.) Revision of design procedures of a project by requesting a preliminary soil survey that will enable the Road Design Section to establish the grade line before the final soil survey and typical section design are accomplished.

3.) Adoption of the R-value method of soil evaluation.

4.) Development of a manual which would explain principals of pavement design and the necessary related data for normal and special conditions.

5.) Development of a regional factor chart that would rate climatic conditions more specifically within Montana.

6.) Encouragement or requirement of completing gravel exploration at an earlier date in a project's design.

7.) Revision and modernization of the gravel files via the computer facilities.

8.) Revision of gravel pit depletion reports.

9.) Establishment of minimum surfacing depths.

10.) Establishment of wearing course thickness policy on the basis of traffic volume.

11.) Initiation of a research program to evaluate the designs that have been constructed.

REFERENCES

1. "Report of Committee on Classification of Materials for Subgrades and Granular Type Roads", Highway Research Board Proceedings, Vol. 25, pp 375-392, (1945).
2. AASHO Interim Guide for the Design of Flexible Pavement Structures, AASHO Committee on Design, (1961).
3. Montana Annual Loadometer Survey, Planning Survey Division, Montana Highway Department and Bureau of Public Roads, (August, 1965).
4. Grubbs, Edward C. and Roberts, Freddy L., A correlation Study of California R-Value and AASHO Group Index for Arkansas Soils, The University of Arkansas, Civil Engineering Department, Technical Report No. 2 of Highway Research Project No. 20, (May, 1966).
5. Hveem, F.N. and Carmany, R. M., "The Factors underlying the Rational Design of Pavements," Highway Research Board Proceedings, Vol. 28, pp 101-136, (1948).
6. Hveem, F. N., and Sherman, G. B., "Thickness of Flexible Pavements by the California Formula Compared to the AASHO Road Test Data," Highway Research Record, No. 13, pp 142-167,(June, 1963).
7. Soils Manual for Design of Asphalt Pavement Structures, The Asphalt Institute, Manual Series No. 10, (First Edition),(June, 1961).
8. Linell, K. A., Henion, F. B., and Lobocz, E. F., "Corps of Engineers' Pavement Design in Areas of Seasonal Frost", Highway Research Record, No. 33, pp 76-136, (1963).
9. Erickson, L.E. An Evaluation of Flexible Pavement Design Methods, State of Idaho Department of Highways, Research Project No. 20, (May, 1964).

10. "Planning Manual", Part 7, - Design, "Structural Design of the Roadbed", State of California, Department of Public Works, Division of Highways, (1959).

CLASSIFICATION OF HIGHWAY SUBGRADE MATERIALS
(With Suggested Subgroups)

General Classification	Granular Materials (35% or less passing No. 200)							Silt-Clay Materials (More than 35% passing No. 200)			
	A-1			A-2							A-7
Group Classification	A-1-a	A-1-b	A-3	A-2-4	A-2-5	A-2-6	A-2-7	A-4	A-5	A-6	A-7-5, A-7-6
Sieve Analysis, Percent passing:											
No. 10	50 max.										
No. 40	30 max.	50 max.	51 min.								
No. 200	15 max.	25 max.	10 max.	35 max.	35 max.	35 max.	35 max.	36 min.	36 min.	36 min.	36 min.
Characteristics of fraction passing No. 40:											
Liquid limit				40 max.	41 min.	40 max.	41 min.	40 max.	41 min.	40 max.	41 min.
Plasticity index	6 max.		N.P.	10 max.	10 max.	11 min.	11 min.	10 max.	10 max.	11 min.	11 min.[a]
Group Index[b]	0		0	0		4 max.		8 max.	12 max.	16 max.	20 max.
Usual Types of Significant Constituent Materials	Stone Fragments, Gravel and Sand		Fine Sand	Silty or Clayey Gravel and Sand				Silty Soils		Clayey Soils	
General Rating as Subgrade	Excellent to Good					Fair to Poor					

Classification Procedure: With required test data available, proceed from left to right on above chart and correct group will be found by process of elimination. The first group from the left into which the test data will fit is the correct classification.

[a] Plasticity index of A-7-5 subgroup is equal to or less than LL minus 30. Plasticity index of A-7-6 subgroup is greater than LL minus 30 (see figure 2).

[b] See group index formula and Figure 1 for method of calculation. Group index should be shown in parentheses after group symbol as: A-2-6(3), A-4(5), A-6(12), A-7-5(17), etc.

No. 1

TABLE 3

GROUP INDEX FORMULA

Group index = 0.2a + 0.005 ac + 0.01 bd

In which

a = That portion of percentage passing No. 200 sieve greater than 35 and not exceeding 75, expressed as a positive whole number (1 to 40).

b = That portion of percentage passing No. 200 sieve greater than 15 per cent and not exceeding 55 percent, expressed as a positive whole number (1 to 40).

c = That portion of the numerical liquid limit greater than 40 and not exceeding 60, expressed as a positive whole number (1 to 20).

d = That portion of the numerical plasticity index greater than 10 and not exceeding 30, expressed as a positive whole number (1 to 20).

The following are examples of calculation of the group index:

(1) An A-6 material has 65 percent passing . 200 sieve, liquid limit of 32 and plasticity index of 13. The calculation is as follows:

a = 65 − 35 = 30

b = 55 − 15 = 40 (55 is substituted for 65 as critical range is 15 to 55)

c = zero, since liquid limit is below 40

d = 13 − 10 = 3

Group index = .2 × 30 + .01 × 40 × 3 = 7.2 (Should be recorded to nearest whole number which is 7).

2) An A-7 material has 54 percent passing No. 200 sieve, liquid limit of 62 and plasticity index of 33. The calculation is as follows:

= 54 − 35 = 19

b = 54 − 15 = 39

c = 60 − 40 = 20 (60 is substituted for 62 as critical range is 40 to 60)

d = 30 − 10 = 20 (30 is substituted for 33 as critical range is 10 to 30)

Group index = .2 × 19 + .005 × 19 × 20 + 01 × 39 × 20 = 13.5 (13)

Charts for graphical determination of group index are shown on figure 1.

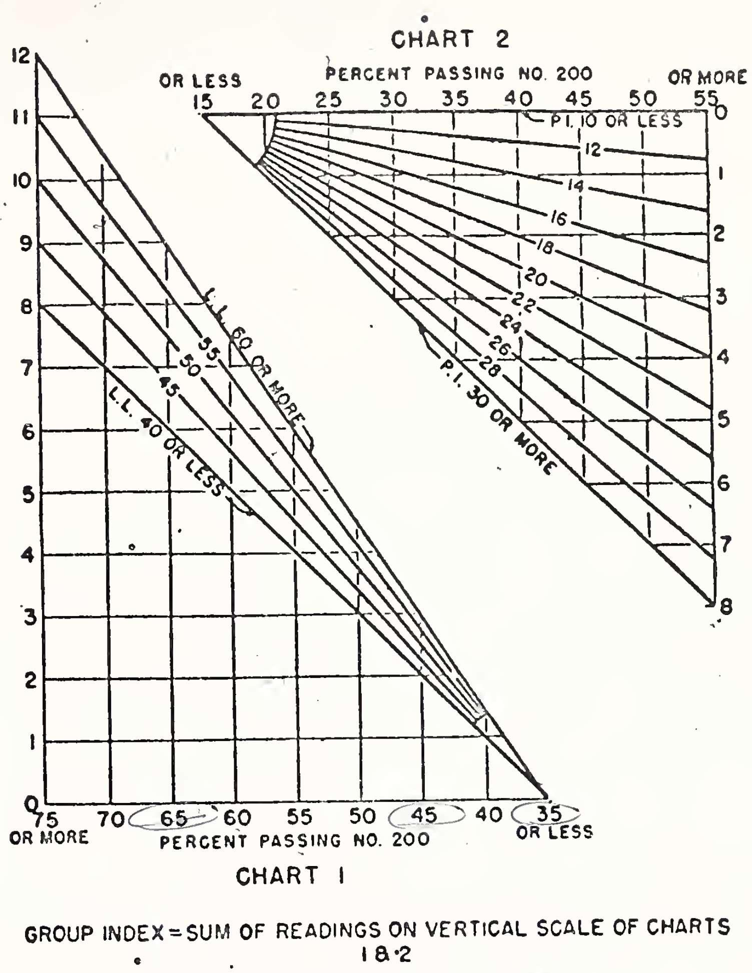


Figure 1. Group Index Charts

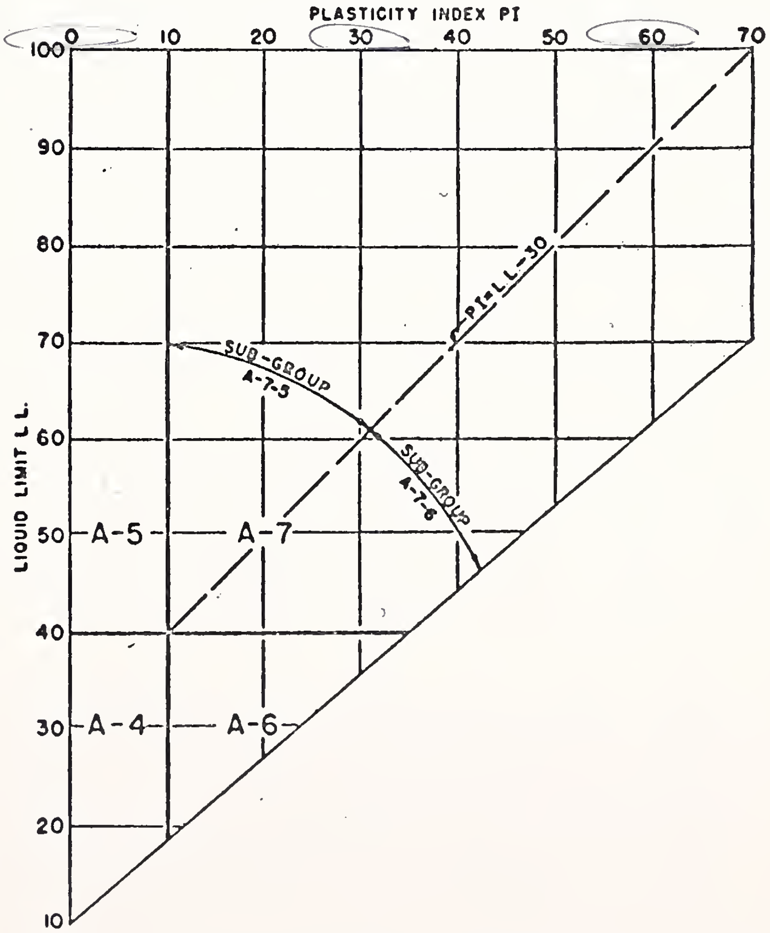


Figure 2. Liquid Limit and Plasticity Index Ranges for the A-4, A-5, A-6 and A-7 Subgrade Groups

MONTANA HIGHWAY DEPARTMENT

APPLICATION OF THE CLASSIFICATIONS AND GROUP INDEX OF SUBGRADE SOILS IN ESTIMATING DESIRABLE SUBBASE AND TOTAL PAVEMENT THICKNESS.

REFERENCE: DATA TAKEN FROM "CLASSIFICATION OF SOILS AND SUBGRADE MATERIALS FOR HIGHWAY CONSTRUCTION PURPOSES" - ADOPTED BY HIGHWAY RESEARCH BOARD - 1945 (SEE VOL. 25)

GROUP INDEX OF SUBGRADE ALLEN CLASSIFICATION	TRAFFIC VOLUME LESS THAN 50 VEHICLES PER DAY - THICKNESS INCHES				TRAFFIC VOLUME 50 TO 300 VEHICLES PER DAY - THICKNESS INCHES				TRAFFIC VOLUME MORE THAN 300 VEHICLES PER DAY - THICKNESS INCHES			
	SURF. & BASE COURSE (NO SEL. MTR'L. SUBBASE)	COMBINATION OF SURFACE, BASE & SELECTED MATERIAL SUBBASE COURSES			SURF. & BASE COURSE (NO SEL. MTR'L. SUBBASE)	COMBINATION OF SURFACE, BASE & SELECTED MATERIAL SUBBASE COURSES			SURF. & BASE COURSES (NO SEL. MTR'L. SUBBASE)	COMBINATION OF SURFACE, BASE & SELECTED MATERIAL SUBBASE COURSES		
		SURFACE AND BASE	SEL. MTR'L. SUBBASE	TOTAL		SURFACE AND BASE	SEL. MTR'L. SUBBASE	TOTAL		SURFACE AND BASE	SEL. MTR'L. SUBBASE	TOTAL
1	2	3	4	5	6	7	8	9	10	11	12	13
EXCELLENT, A-1-a	2	2	0	2	5	5	0	5	8	8	0	8
GOOD, 0 TO 1	6	6	0	6	9	9	0	9	12	12	0	12
2	7	6	2	8	10	9	2	11	13	12	2	14
3	7	6	3	9	10	9	3	12	13	12	3	15
4	8	6	4	10	11	9	4	13	14	12	4	16
5	8	6	5	11	11	9	5	14	14	12	5	17
6	9	6	6	12	12	9	6	15	15	12	6	18
7	9	6	6	12	12	9	6	15	15	12	6	18
8	9	6	7	13	12	9	7	16	15	12	5	19
9	10	6	8	14	13	9	8	17	16	12	8	20
10	10	6	9	15	13	9	9	18	16	12	9	21
11	10	6	9	15	13	9	9	18	16	12	9	21
12	11	6	10	16	14	9	10	19	17	12	10	22
13	11	6	10	16	14	9	10	19	17	12	10	22
14	11	6	10	16	14	9	10	19	17	12	10	22
15	11	6	11	17	14	9	11	20	17	12	11	23
16	11	6	11	17	14	9	11	20	17	12	11	23
17	12	6	11	17	15	9	11	20	18	12	11	23
18	12	6	12	18	15	9	12	21	18	12	12	24
19	12	6	12	18	15	9	12	21	18	12	12	24
20	12	6	12	18	15	9	12	21	18	12	12	24

NOTE:- SELECT MATERIAL SUBBASE AS LISTED ON THE CHART IS IDENTICAL WITH THE SOIL LISTED IN THE SECOND ENTRY OF COLUMN 1 OF THE CHART AS "GOOD, 0 TO 1," AND IS DEFINED FURTHER AS MATERIAL WHICH INCLUDES THE COMMON RUN OF FINE SANDS, SILTY SANDS, AND SILTY OR CLAYEY GRAVELS WHICH HAVE A GROUP INDEX OF ZERO, WITH A TOLERANCE OF ONE. EXCEPTING THE "EXCELLENT, A-1-a" MATERIAL, THESE MATERIALS WILL USUALL FALL IN GROUPS A-1-b, A-3, AND A-2, ALTHOUGH THE TOLERANCE OF ONE WILL PERMIT INCLUSION OF BORDER LINE GRANULAR MATERIALS FALLING IN OTHER GROUPS.

MONTANA STATE HIGHWAY COMMISSION

APPLICATION OF THE CLASSIFICATIONS AND GROUP INDEX OF SUBGRADE SOILS IN ESTIMATING DESIRABLE SUBBASE AND TOTAL PAVEMENT THICKNESS.

Reference: Data Taken From "Classification Of Soils And Subgrade Materials For Highway Construction Purposes" Adopted By Highway Research Board - 1945 (See Vol. 25). Revised December 15, 1955.

CONVERSION EQUIVALENTS	INCHES TO FEET
1 in	0.10 Ft
2 in	0.15 Ft
2½ in	0.20 Ft
3 in	0.25 Ft
4 in	0.35 Ft
5 in	0.40 Ft
6 in	0.50 Ft
7 in	0.60 Ft
8 in	0.70 Ft
9 in	0.75 Ft
10 in	0.85 Ft
11 in	0.90 Ft
12 in	1.00 Ft

GROUP INDEX OF SUBGRADE	THICKNESS IN FEET																							
	TRAFFIC VOLUME																							
	Less Than 100 Vehicles Per Day				100 to 300 Vehicles Per Day								More Than 300 Vehicles Per Day								Special Design Only			
					DRY AREAS				WET AREAS				DRY AREAS				WET AREAS							
	SURFACE & BASE COURSES ONLY	Combination Of Surface, Base & Sel. Mt'l Subbase Courses			SURFACE & BASE COURSES ONLY	Combination Of Surface, Base & Sel. Mt'l Subbase Courses			SURFACE & BASE COURSES ONLY	Combination Of Surface, Base & Sel. Mt'l Subbase Courses			SURFACE & BASE COURSES ONLY	Combination Of Surface, Base & Sel. Mt'l Subbase Courses			SURFACE & BASE COURSES ONLY	Combination Of Surface, Base & Sel. Mt'l Subbase Courses			SURFACE & BASE COURSES ONLY	Combination Of Surface, Base & Sel. Mt'l Subbase Courses		
		SURF & BASE	SEL MAT'L SUBBASE	TOTAL		SURF & BASE	SEL MAT'L SUBBASE	TOTAL		SURF & BASE	SEL MAT'L SUBBASE	TOTAL		SURF & BASE	SEL MAT'L SUBBASE	TOTAL		SURF & BASE	SEL MAT'L SUBBASE	TOTAL		SURF & BASE	SEL MAT'L SUBBASE	TOTAL
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Excellent A-1-a	0.15	0.15	0.00	0.15	0.40	0.40	0.00	0.40	0.50	0.50	0.00	0.50	0.60	0.60	0.00	0.60	0.70	0.70	0.00	0.70	0.70	0.70	0.00	0.70
Good 0 to 1	0.50	0.50	0.00	0.50	0.75	0.75	0.00	0.75	0.90	0.90	0.00	0.90	1.00	1.00	0.00	1.00	1.00	1.00	0.00	1.00	1.00	1.00	0.00	1.00
2	0.60	0.50	0.20	0.70	0.85	0.75	0.15	0.90	1.00	0.90	0.15	1.10	1.10	1.00	0.15	1.15	1.20	1.20	0.20	1.40	1.30	1.30	0.30	1.60
3	0.60	0.50	0.25	0.75	0.85	0.75	0.25	1.00	1.00	0.90	0.25	1.15	1.10	1.00	0.25	1.25	1.30	1.20	0.35	1.55	1.50	1.30	0.40	1.70
4	0.70	0.50	0.35	0.85	0.90	0.75	0.35	1.10	1.10	0.90	0.35	1.25	1.15	1.00	0.35	1.35	1.40	1.20	0.40	1.60	1.60	1.30	0.50	1.60
5	0.70	0.50	0.40	0.90	0.90	0.75	0.40	1.15	1.10	0.90	0.40	1.30	1.15	1.00	0.40	1.40	1.40	1.20	0.50	1.70	1.60	1.30	0.60	1.90
6	0.75	0.50	0.50	1.00	1.00	0.75	0.50	1.25	1.15	0.90	0.50	1.40	1.25	1.00	0.50	1.50	1.50	1.20	0.60	1.80	1.70	1.30	0.70	2.00
7	0.75	0.50	0.50	1.00	1.00	0.75	0.50	1.25	1.15	0.90	0.50	1.40	1.25	1.00	0.50	1.50	1.50	1.20	0.60	1.80	1.70	1.30	0.70	2.00
8	0.75	0.50	0.60	1.10	1.00	0.75	0.60	1.35	1.15	0.90	0.60	1.50	1.25	1.00	0.60	1.60	1.50	1.20	0.70	1.90	1.70	1.30	0.80	2.10
9	0.85	0.50	0.70	1.15	1.10	0.75	0.70	1.45	1.25	0.90	0.70	1.60	1.35	1.00	0.70	1.70	1.60	1.20	0.85	2.05	1.80	1.30	0.90	2.20
10	0.85	0.50	0.75	1.25	1.10	0.75	0.75	1.50	1.25	0.90	0.75	1.65	1.35	1.00	0.75	1.75	1.60	1.20	0.90	2.10	1.80	1.30	1.00	2.30
11	0.85	0.50	0.75	1.25	1.10	0.75	0.75	1.50	1.25	0.90	0.75	1.65	1.35	1.00	0.75	1.75	1.60	1.20	0.90	2.10	1.80	1.30	1.00	2.30
12	0.90	0.50	0.85	1.35	1.15	0.75	0.85	1.60	1.35	0.90	0.85	1.75	1.40	1.00	0.85	1.85	1.70	1.20	1.00	2.20	1.90	1.30	1.10	2.40
13	0.90	0.50	0.85	1.35	1.15	0.75	0.85	1.60	1.35	0.90	0.85	1.75	1.40	1.00	0.85	1.85	1.70	1.20	1.00	2.20	1.90	1.30	1.10	2.40
14	0.90	0.50	0.85	1.35	1.15	0.75	0.85	1.60	1.35	0.90	0.85	1.75	1.40	1.00	0.85	1.85	1.70	1.20	1.00	2.20	1.90	1.30	1.10	2.40
15	0.90	0.50	0.90	1.40	1.15	0.75	0.90	1.65	1.35	0.90	0.90	1.80	1.40	1.00	0.90	1.90	1.70	1.20	1.10	2.30	1.90	1.30	1.20	2.50
16	0.90	0.50	0.90	1.40	1.15	0.75	0.90	1.65	1.35	0.90	0.90	1.80	1.40	1.00	0.90	1.90	1.70	1.20	1.10	2.30	1.90	1.30	1.20	2.50
17	1.00	0.50	0.90	1.40	1.25	0.75	0.90	1.65	1.40	0.90	0.90	1.80	1.50	1.00	0.90	1.90	1.80	1.20	1.10	2.30	2.00	1.30	1.20	2.50
18	1.00	0.50	1.00	1.50	1.25	0.75	1.00	1.75	1.40	0.90	1.00	1.90	1.50	1.00	1.00	2.00	1.80	1.20	1.20	2.40	2.00	1.30	1.30	2.60
19	1.00	0.50	1.00	1.50	1.25	0.75	1.00	1.75	1.40	0.90	1.00	1.90	1.50	1.00	1.00	2.00	1.80	1.20	1.20	2.40	2.00	1.30	1.30	2.60
20	1.00	0.50	1.00	1.50	1.25	0.75	1.00	1.75	1.40	0.90	1.00	1.90	1.50	1.00	1.00	2.00	1.80	1.20	1.20	2.40	2.00	1.30	1.30	2.60

NOTE:-Select Material Subbase As Listed On The Chart Is Identical With The Soil Listed In The Second Entry Of Column 1 Of The Chart As "Good, 0 To 1," And Is Defined Further As Material Which Includes The Common Run Of Fine Sands, Silty Sands, And Silty Or Clayey Gravels Which Have A Group Index Of Zero, With A Tolerance Of One Excepting The "Excellent A-1-a Material, These Materials Will Usually Fall In Groups A-1-b, A-3 And A-2, Although The Tolerance Of One Will Permit Inclusion Of Border Line Granular Materials Falling In Other Groups.

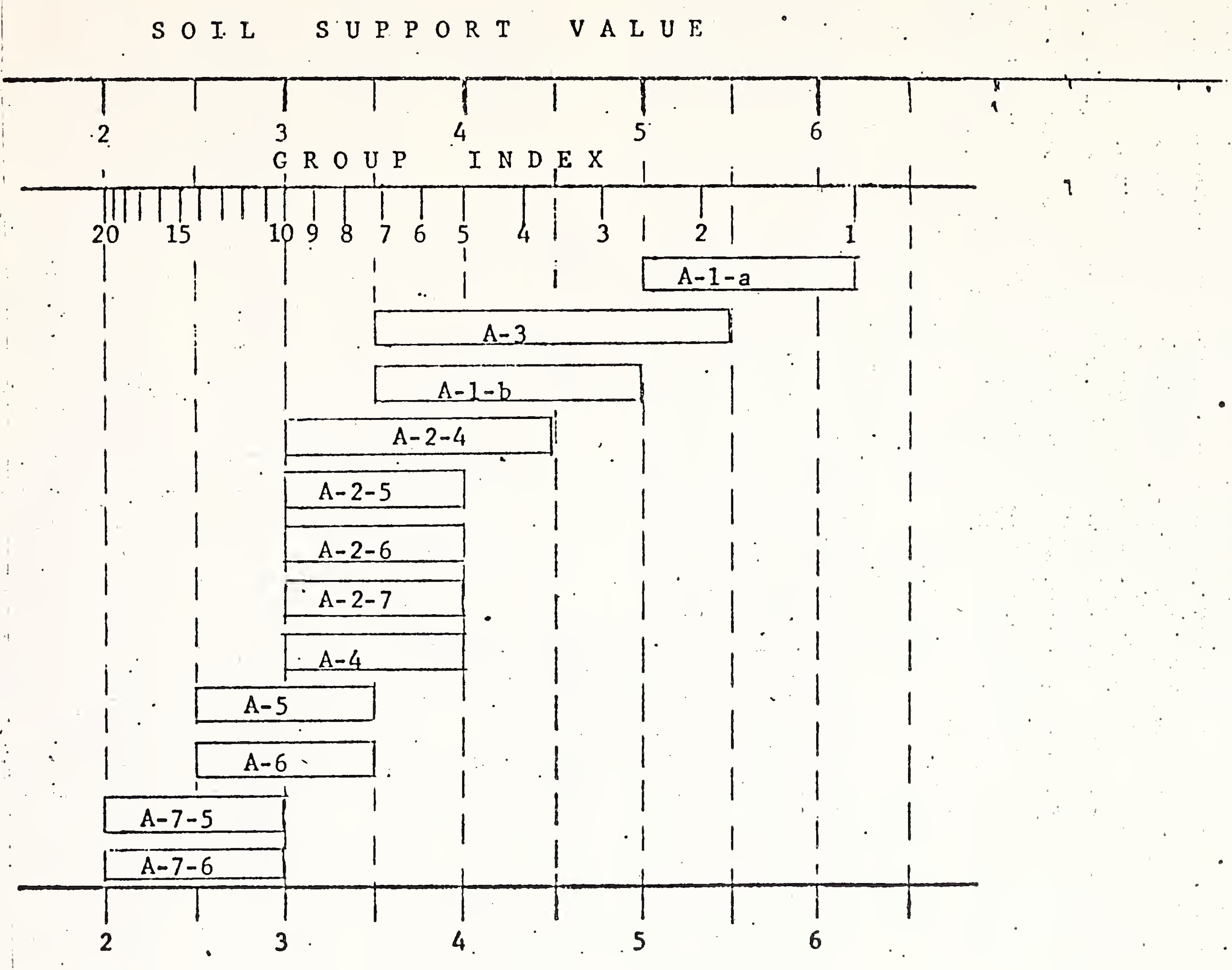
Use Column Listings Under "DRY AREAS" For High, Well Drained Bench Locations And Column Listings Under "WET AREAS" For Valley And Lowland Locations Shown In The Chart For Traffic Volumes Over 100 Vehicles Per Day.

Use A Minimum Of 1.0 Foot Of Select Material Subbase On All Embankment Soils Having Maximum Densities Of Less Than 90 Pounds Per Cubic Foot, Usually Glacial Tills In The A-4 Or A-5 Soils Classification.

APPROVED 1-1-59

STATE HIGHWAY ENGINEER

3


SOIL SUPPORT VALUE
2
3
4
5
6
GROUP INDEX
20
15
10
9
8
7
6
5
4
3
2
1
A-1-a
A-3
A-1-b
A-2-4
A-2-5
A-2-6
A-2-7
A-4
A-5
A-6
A-7-5
A-7-6
2
3
4
5
6

MONTANA HIGHWAY COMMISSION

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STATE HIGHWAY ENGINEER

HELENA, MONTANA 59601

September 29, 1966

IN REPLY REFER TO:
32-DLR

Loadometer Survey
Wheel Load Factors

Bureau of Public Roads
elena, Montana 59601

Gentlemen:

e have reviewed the recently published Montana Annual Loadometer Survey and analyzed in particular the equivalent 18 Kip single axle load factors per 1000 trucks. The principle factors with which we are involved are those for Main Rural, All Urban, and Interstate ural flexible pavement. As you know, for the preceding year these factors were determined by averaging the results from 1963 and 1964 reported in the 1964 Loadometer Survey. Comparison of the factors from the recent survey shows correlation in some cases and ignificant differences in others. The following table illustrates this comparison.

	1964 Survey			1965 Survey			
	1963	1964		1964	1965		
ain Rural (Primary)	243.9	215.2	(229.6*)	214.6	212.0	(213.2**)	223.4
All Urban (Primary & Inter.)	160.9	218.8	(189.8*)	219.3	162.3	(190.8**)	180.7
nterstate Rural	364.5	290.6	(327.5*)	238.6	314.8	(276.7**)	323.3

* Average of 1963 & 1964 values in 1964 Survey used for design factors preceding year.
* Average of 1964 & 1965 values in 1965 Survey.

The final column on the right of the above table represents the average of the 1963 and 1964 alues from the 1964 survey, plus the 1965 value from the 1965 survey. It is our feeling hat these values represent the best correlation to the values and would be the most appropriate for designing purposes.

hus it is proposed to use the values of 223.4, 180.7, and 323.3 as the equivalent 18 Kip Single Axle wheel loads per 1000 trucks for Primary Rural, Primary and Interstate Urban, nd Interstate Rural highways respectively in flexible pavement design for the oncoming ear. Your comment on this proposal in the near future would be greatly appreciated.

Very truly yours,

PAUL M. JOHNSON, P.E.
State Highway Engineer

By Jack R. Beckert
Jack R. Beckert,
Preconstruction Engineer

30-JRB;MRW;DLR:fe
n triplicate

cc: D. L. Rydquist ✓

Surfacing Coefficients for Pavement Structural Components

Surface Courses

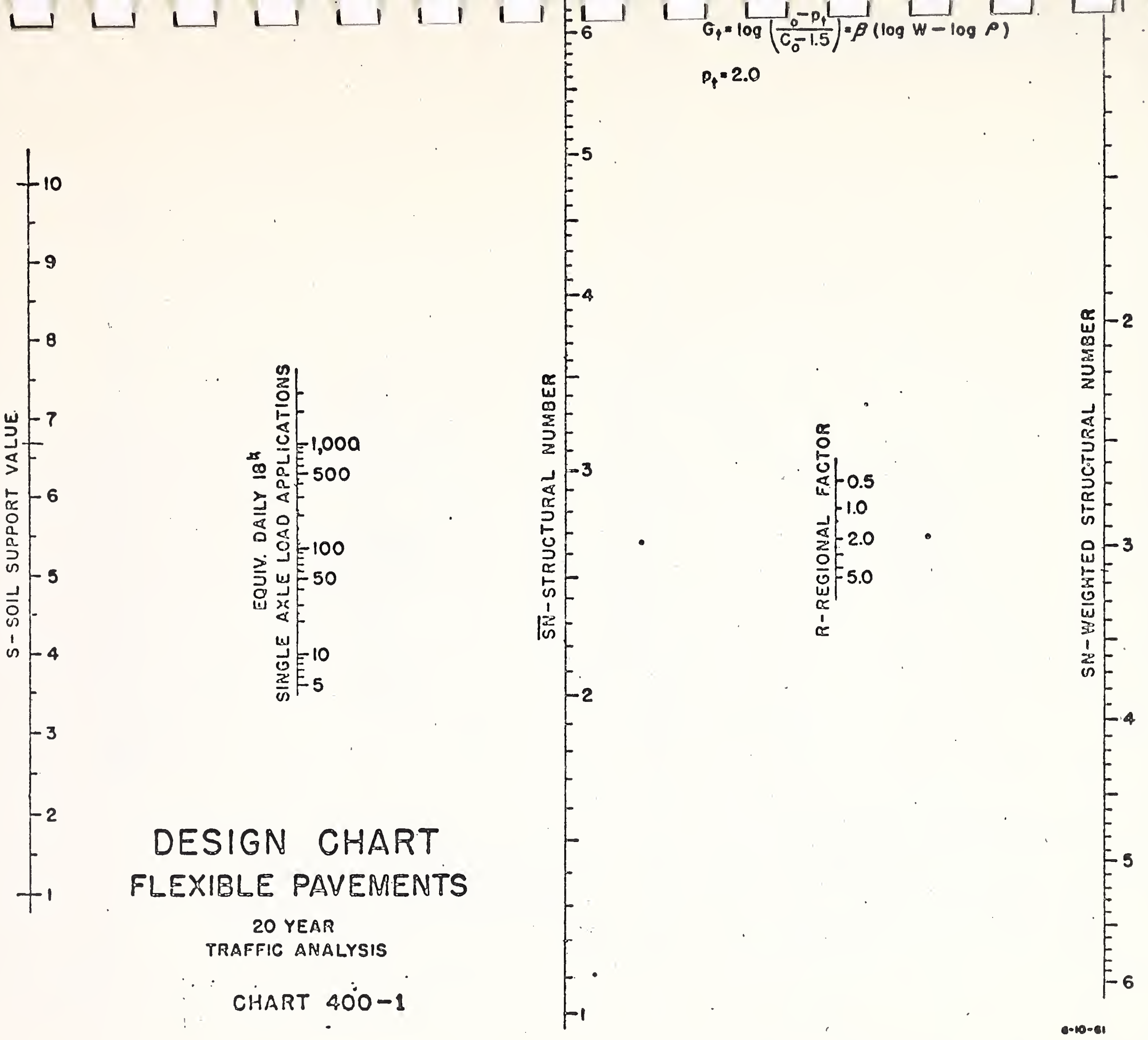
Plant Mix, Type 3	0.40
Plant Mix, Type 2	0.35
Plant Mix, Type 1	0.30
Road Mix	0.20
Crushed Gravel	0.14

Treated Base Courses

Plant Mix Base	0.30
Bituminous Stabilized	0.20
Cement Treated +400 psi at 7 days	0.20
Cement Treated -400 psi at 7 days	0.15
Lime Treated	0.15 - 0.20

Gravel Base Courses

Crushed Gravel 1½" max.	0.14
Crushed Gravel over 1½"	0.12
Selected Surfacing	0.10
Special Borrow	0.07
Sand Surfacing	0.05



$$G_t = \log\left(\frac{C_o - p_t}{C_o - 1.5}\right) = \beta(\log W - \log \rho)$$

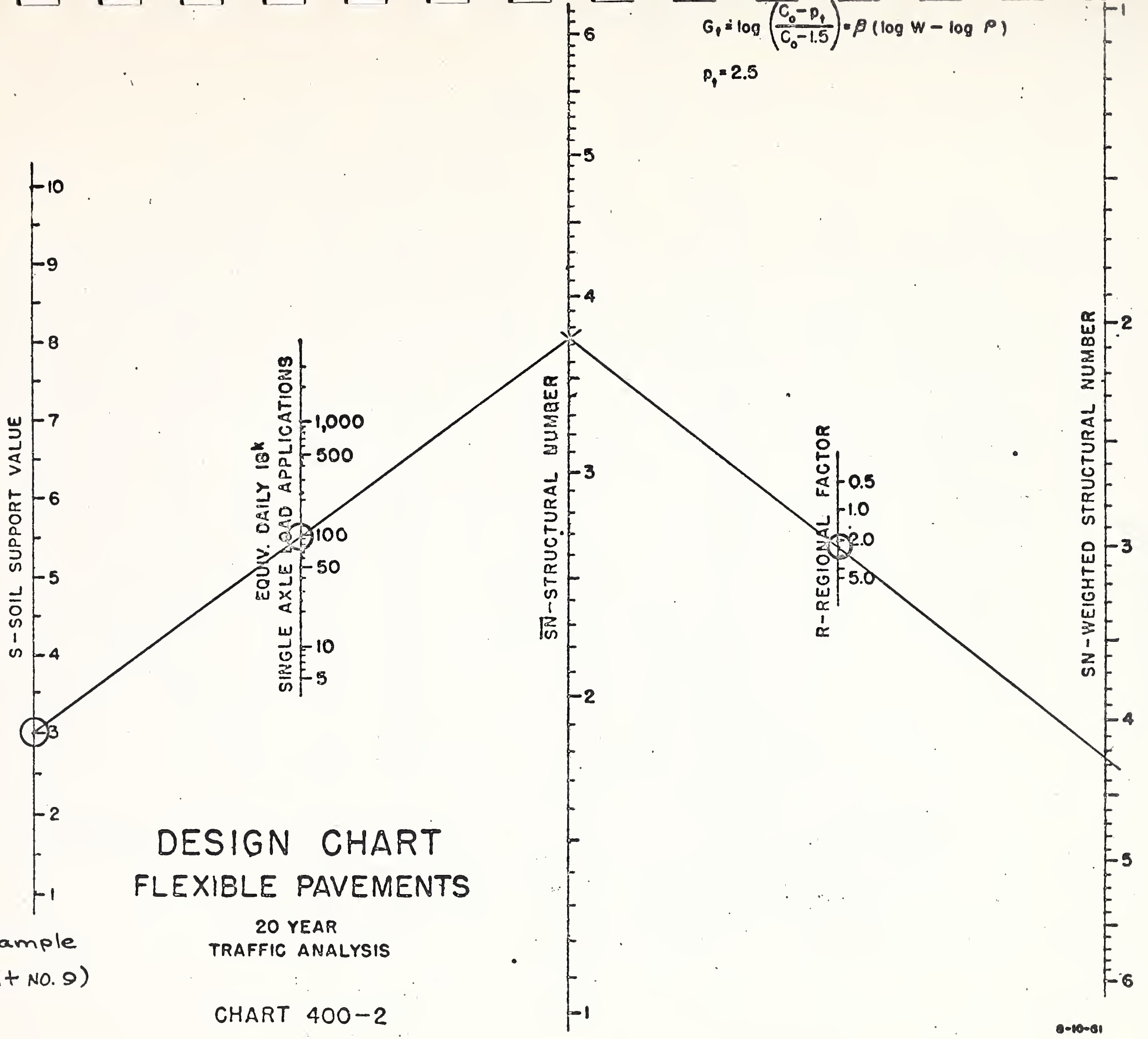
$p_t = 2.0$

DESIGN CHART
FLEXIBLE PAVEMENTS

20 YEAR
TRAFFIC ANALYSIS

CHART 400-1

6-10-61



$$G_t = \log\left(\frac{C_0-p_t}{C_0-1.5}\right) = \beta(\log W - \log \rho)$$

$p_t = 2.5$

DESIGN CHART
FLEXIBLE PAVEMENTS

20 YEAR
TRAFFIC ANALYSIS

CHART 400-2

○ Values for example problem (Exhibit NO. 9)

8

FLEXIBLE PAVEMENT DESIGN EXAMPLE

Assume the following situation:

A primary 2-lane highway in a rural area.

ADT - 1967 = 2,000 ADT - 1987 = 3,600

% all trucks including pickups and panels = 30%

Subgrade soil will be A-4(8) material

Regional Factor = 2.5

Serviceability Index = 2.5

1. SOILS

From Soil Support Value Chart (Exhibit No. 4) the "Soil Support Value" will be 3.0 for an A-4(8) Soil

2. TRAFFIC

The average 20 year traffic per lane is the design volume.

2000
+ 3600
5600 ÷ 2 = 2,800 ADT/2 lanes = 1,400 ADT/lane

(1,400) (30% all trucks) = 420 ADTT

From Exhibit No. 5 it can be seen that the Equivalent wheel load factor for a primary rural highway is 223.4/1000.

Thus: (420)(223.4/1000) = 94 Equiv. 18 Kip Single Axle Wheel Loads/day.

3. MATERIALS

From Chart 400-2 (Exhibit No. 8) the SN value required = 4.25.

Then applying the surfacing coefficients from Exhibit No. 6

Depth	Course	Surf. Coef.			SN.
0.25' = 3"	Plant Mix, Type 3	0.40	x 3	=	1.20
0.20' = 2½"	Cr. Top Surf.	0.14	x 2½	=	0.35
0.50' = 6"	Cr. Base Crse.Gr.5(1½")	0.14	x 6	=	0.84
1.35' = 16"	Cr. Base Crse.Gr.2(3")	0.12	x 16	=	1.92
		Total SN		=	4.31
		Exceeds Required			4.25

The above section would be structurally adequate for the conditions of this project. However it is not necessarily the one that would be used as further investigation into the possibility of stabilized bases being used would be conducted. The final design would generally be dependent upon the results of an economic comparison which in turn is dependent upon the surfacing materials available for the project.

AB.F NO.
REV. 5 S HI AY C ISSION S T S TS

PRECONSTRUCTION SOIL SURVEY DATA, & SPECIAL RECOMMENDATIONS RELATIVE SUBGRADE & ROAD SURFACE DESIGN

DATE: ______

PROJ. NO. ______ LENGTH ______ MILES,: COUNTY ______

SUBMITTED BY: ______ TITLE: ______ DIV. ______

APPROVED: ______ DIV. ENGR. ______ DIST.ENGR.

UNIFORM SOIL SECTIONS		SOILS GROUP	SOILS													
			CONSTANTS		GRADING											
STATION	STATION		LIQUID LIMIT	PLASTICITY INDEX	% PASS 10 MESH	% PASS 40 MESH	% PASS 200 MESH	SOIL SAMPLE NUMBER	UNDISTURBED DENSITY	MAXIMUM DENSITY	% NATURAL MOISTURE CONTENT	OPTIMUM MOISTURE	DRAINAGE OR DEPTH TO WATER TABLE		RECOMMENDED TOTAL THICKNESS OF SURFACING	EXHIBIT NO. OF ATTACHED RECOMMENDATIONS OR UNUSUAL CONDITIONS

FORM T-148

STANDARD SOIL SURVEY SHEET

PROJECT F-059-1(5)
A.F.E. NO. F-059-1(1)

SHEET NO.	TOTAL SHEETS
4	4

Laboratory No.	523-63	524-63	525-63	526-63	527-63	528-63	529-63	530-63
Field No.	1	2	3	4	5	6	7	8
Station Sampled	0+40	0+40	4+30	18+70	18+70	18+70	26+00	26+00
Maximum Size		1/2"	3"		2"			
Passing No. 4	100	98	50	—	82	100	100	100
Passing No. 10	99	96	48	100	70	97	100	99
Passing No. 40	96	92	44	92	61	94	97	97
Passing No. 200	41	41	11	58	24	83	62	51
Liquid Limit	27	32	NV	55	25	46	30	38
Plastic Index	3	12	NP	21	NP	28	15	17
Classification	A-4(1)	A-6(2)	A-1-b(0)	A-7-5(11)	A-2-4(0)	A-7-6(16)	A-6(7)	A-6(5)
"R" Value	42	44	MAX.	21	68	14	33	32
Cover Required	14 6"	14 0"		21 0"	6 2"	23 0"	17 3"	17 6"
IN PLACE MOIST.		8.3%	2.0%				9.8%	10.1%

VARIABLE SURFACING SECTION

Station	Station	S.E.	Sub-base
0+00	10+00		
10+00	35+00		

Notes

1. WASTE SAMPLE #4 FROM STA 16+00 TO STA. 19+75
2. FROM STA. 0+00 TO 10+00 WILL TOP WITH 18" OF SAMPLE #3. THIS WILL INCLU CUT SECTION.

Design Factors

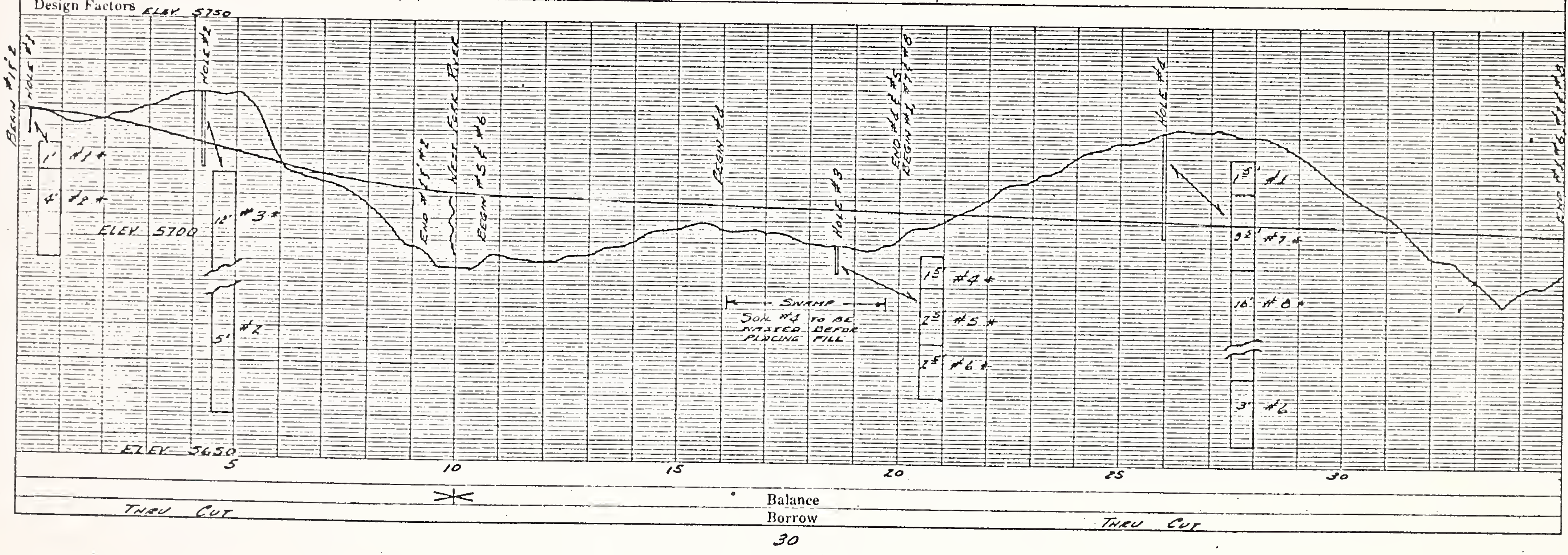
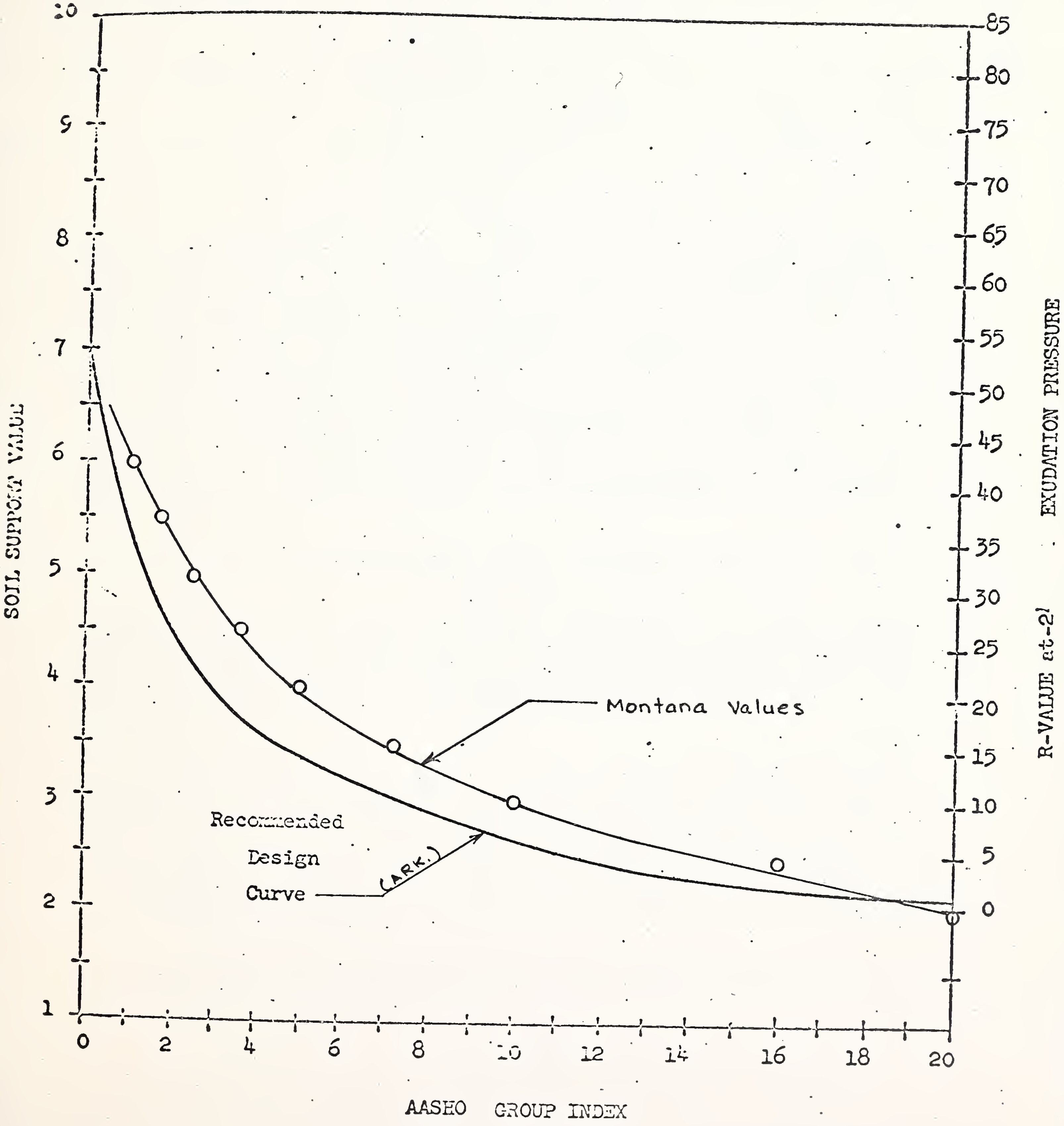


Figure 8


SOIL SUPPORT VALUE
1
2
3
4
5
6
7
8
9
10
EXUDATION PRESSURE
R-VALUE at-2'
85
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
0
2
4
6
8
10
12
14
16
18
20
Montana Values
Recommended
Design
Curve
(ARK.)
AASHO GROUP INDEX

Form CD-121 (11-63) by 206-10)

UNITED STATES GOVERNMENT

Memorandum

U.S. DEPARTMENT OF COMMERCE
BUREAU OF PUBLIC ROADS

MONTANA HIGHWAY COMMISSION
MAR - 5 1965
HELENA, MONTANA

ACT	INF	RETURN TO MAIN FILE	
	1	STATE HWY ENGR	a
	2	DEP ST HWY ENGR	
		BRIDGE	
		CONSTRUCTION	
		MAINTENANCE	
	3	PRECONSTRUCTION	✓
		RIGHT - OF - WAY	
	1	ACCOUNTING	
		MATERIALS	
		OFFICE ENGR	
		PLANNING SURVEY	
4		Bogy	

PAVING
MAR 8 - 1965
ENGINEER

TO : State Highway Commission
Helena, Montana

DATE: March 3, 1965

In reply refer to:

FROM : E. H. Cowan, Division Engineer
Helena, Montana

SUBJECT: Pavement Design

As you know, our engineers are obligated to review your proposed pavement designs on Federal-aid projects. One tool both Mr. Bogy and we have been using is the AASHO Interim Guides for the Design of Flexible and Rigid Pavement Structures. Normally, your designs check reasonably close to this guide when one uses the group index - soil support value chart prepared by Mr. Bogy. You will note however, in Appendix E of the Flexible Guide, that the group index method as set forth in the correlation chart for estimating soil support value does not agree with cooperative testing performed in connection with the AASHO Road Test. Mr. Bogy's chart is somewhat more conservative than the AASHO chart. In order that we can make a more meaningful review of the proposed designs, it is suggested that R values (or CBR's) be determined for the soils in addition to the Allen Classification.

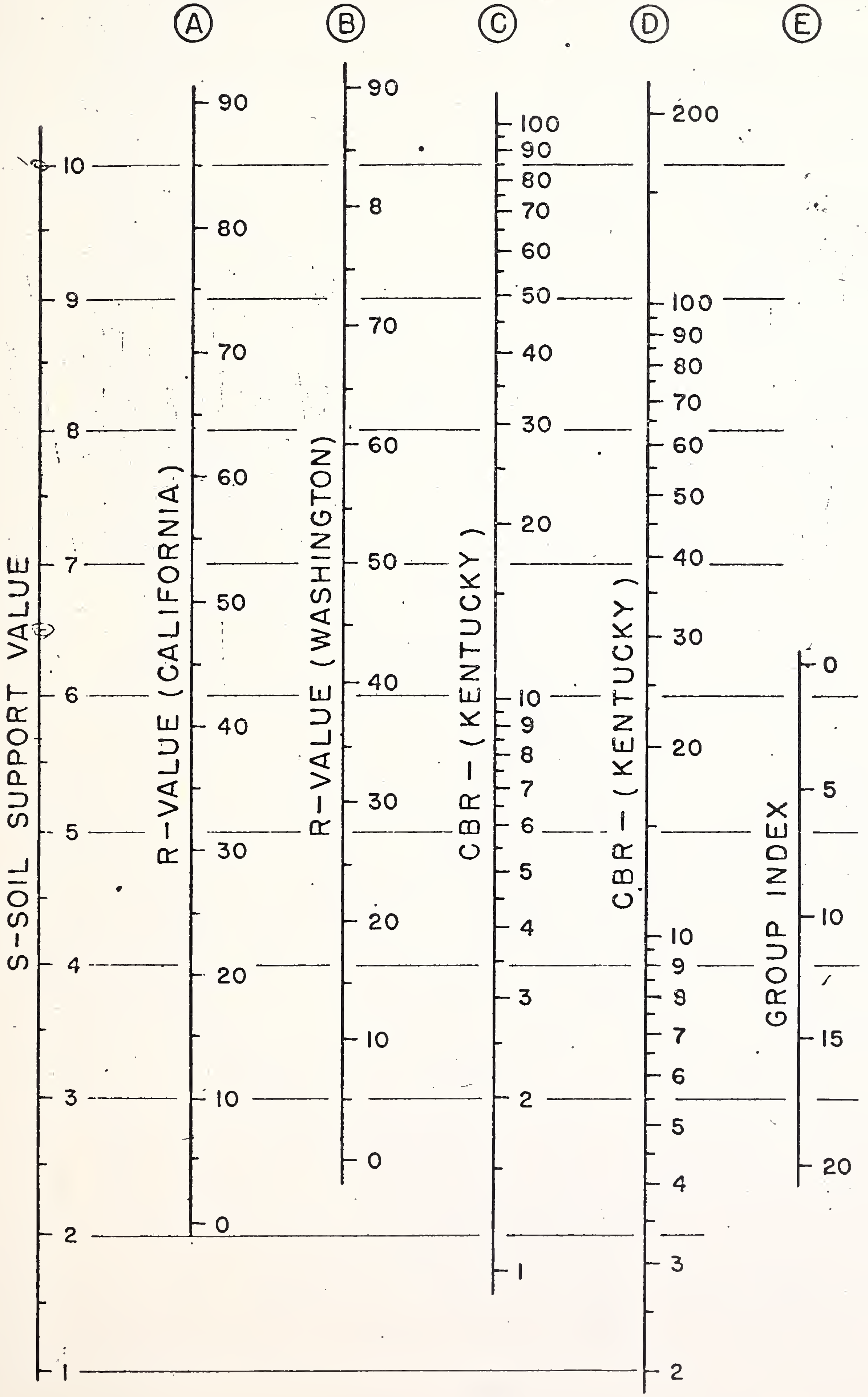
We believe your department would benefit from this additional information.

We have observed that a number of soil profiles still have only limited drilling and testing in the large cuts. We believe more extensive drilling would not only give a better basis for backslope design, but would also present more information as to the type of material that the fills will be constructed of. Of special interest would be drilling all major cuts to grade.

We would also like an opportunity to review any calculations or reports prepared by your department for 18 Kip equivalancy factors per 1000 trucks based on the annual loadometer survey. It appears desirable that general factors should be prepared for Interstate, Primary and Secondary highways if your studies show there is a significant difference. Our agency could use these factors in review of Federal-aid projects as well as in design of Direct Federal Projects.

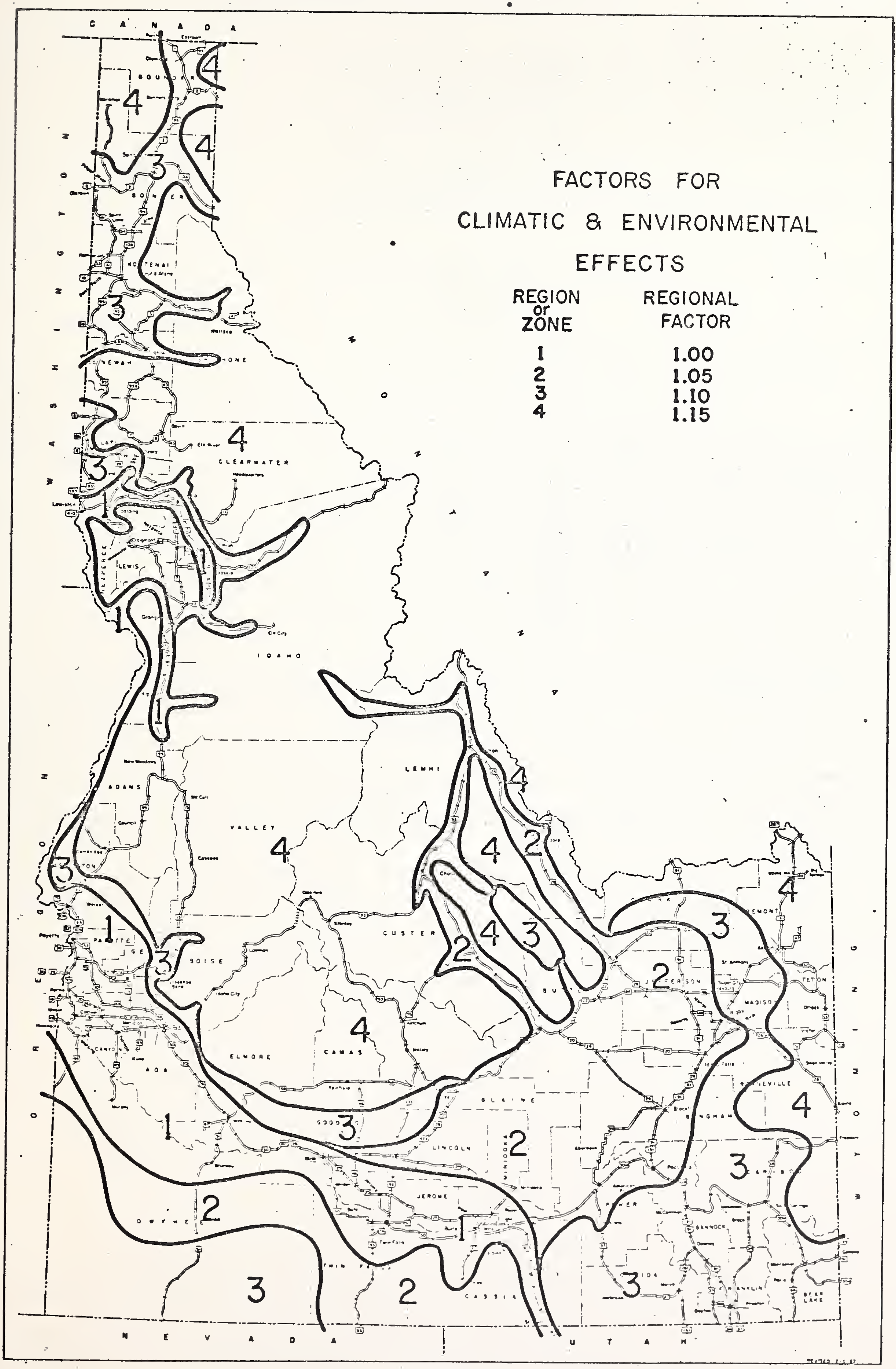
It is hoped that your department concurs with these observations and implements them in the near future.

BUY U.S. SAVINGS BONDS REGULARLY ON THE PAYROLL SAVINGS PLAN



CORRELATION CHART
FOR ESTIMATING
SOIL SUPPORT VALUE (S)

7-26-61



FACTORS FOR
CLIMATIC & ENVIRONMENTAL
EFFECTS

REGION or ZONE	REGIONAL FACTOR
1	1.00
2	1.05
3	1.10
4	1.15

15

APPLICATION TO SECURE MATERIALS SITE

Proj. No.____________

____
(Date)

Div. No.____________ ________________________
(Designation)

Lab. Nos.____________ ________________________

(If materials to be used on other Projs. give nos. here)

TO RIGHT OF WAY DIVISION, Helena:

You are hereby requested to secure materials source herein described which is to be used as a source of ________________________

Acquisition of source should, if possible, be made in the following manner:

(Delete the one not applicable)

(1) Purchase by deed, securing fee simple title

or

(2) Secure temporary agreement to remove materials, payment to be made either by cubic yard or on lump sum basis.

If an agreement is secured it is desired that it be for the following term:

____

____

OWNER OF LAND: ________________________

ADDRESS OF OWNER: ________________________

HAS THE MATERIAL BEEN TESTED AND APPROVED FOR THE USE INTENDED: ____________

____

ESTIMATED YARDAGE IN THE PROPOSED PIT: ________________________

DESCRIPTION OF THE LAND REQUIRED: (It is necessary that a proper legal description of the land be submitted with this application.) It is situated in:

____

____

____

____

____

(PLEASE USE REVERSE SIDE IF NECESSARY

____
(Signature - Preconstruction Engineer)

(If the materials site herein mentioned is to be used in connection with the construc-)
(tion of a project also requiring R/W, it is essential that this application be re-)
(ceived before agent opens negotiations. Upon completion of negotiations, Preconstruc-)
(tion Engineer and District Engineer will receive copies of final report.)

AVAILABLE SURFACING MATERIALS REPORT

Montana State Highway Commission
Helena, Montana.

DATE ____________________

PROJECT NO.: ____________________ LENGTH: __________ MILES

ESTIMATED QUANTITY: ____________________ COUNTY: ____________________

OWNER: ____________________

LOCATION: ____________________

LOCATION FROM PROJECT: ____________________ OUTLET ROAD: ____________________

NOTE: The data shown herein represents condensed information from the Laboratory and as reported by the Field forces, regarding the source of surfacing materials for this project. It does not constitute a guarantee by the State Highway Commission of the quality or quantity of the material as shown, nor does it annul or modify the provisions of the Standard Specifications pertaining to the type of materials which are to be furnished by the contractor, except as the Special Provisions may otherwise provide.

REMARKS: ____________________

LAB. SAMPLE NO.	% OVER-SIZE		GRADING OF MINUS 4 INCH FRACTION Percentages by weight Passing Square Mesh Sieves													WEAR	LIQ. LIMIT	PLASTICITY INDEX	ASTM 8-DAY VOL. SWELL
	OVER 6"	BETWEEN 4" & 6"	4"	3"	2"	1½"	1"	3/4"	1/2"	3/8"	#4	#10	#40	#80	#200				

No. 18

HEEP AREA 5 WORKSHOP
JUNE 27 AND 28, 1966
CARSON CITY, NEVADA

WHAT I WOULD LIKE TO PRESENT TODAY IS AN IDEA OR METHOD RELATED TO MATERIALS ENGINEERING.

BASICALLY, THIS CONSISTS OF BUILDING UP A CARD FILE HISTORY OF TEST REPORTS AND THEN SEARCHING THIS FILE FOR CERTAIN PARAMETERS.

IN THE LAST SEVERAL YEARS, THE BPR HAS BEEN ON AN EXPANDING MATERIALS TESTING PROGRAM. NOW, I AM REFERRING ONLY TO DIRECT FEDERAL WORK AND NOT FEDERAL AID.

TO OUR LOCATION SOILS REPORTS WE HAVE ADDED THE ACTUAL TESTING OF LOCATION AND CONSTRUCTION MATERIALS. IN THE PAST WE HAD EACH RESPECTIVE STATE LAB MAKE THESE TESTS FOR US. NOW WE DO THIS OURSELVES AT VANCOUVER.

WE DO APPROXIMATELY TWO DOZEN DIFFERENT TESTS AT THE PRESENT TIME WHICH AMOUNTS TO ABOUT ONE THOUSAND TESTS RUN PER YEAR, 1,000 FOR SOIL AND 1,000 FOR AGGREGATE.

THERE ARE TWO PROGRAMS INVOLVED HERE AND THEY BOTH USE THE SAME INPUT CARDS EXCEPT THAT THE SECOND ONE USES SOME ADDITIONAL CRITERIA CARDS.

THE FIRST ONE WE CALL MATERIALS LABORATORY LIST AND THE SECOND IS SOIL AND AGGREGATE CORRELATION ANALYSIS, WHICH IS OUR SEARCH PROGRAM.

THE LIST PROGRAM IS JUST THAT. IT HAS TWO PHASES, ONE FOR SOILS AND ONE FOR AGGREGATES. IN THE PAST, TYPISTS HAD TO TRANSFER THE LAB TEST DATA FROM WORK CARDS TO TEST REPORT FORMS. NUMEROUS COPIES WERE DISTRIBUTED TO ALL PARTIES CONCERNED AND MOST OF THE TIME ADDITIONAL THERMOFAX COPIES HAD TO BE MADE. THIS PROCEDURE IS NO LONGER USED BECAUSE THE COMPUTER PRINTER MAKES ALL THE DESIRED COPIES.

THERE ARE LESS ERRORS ON OUR MACHINE-PRODUCED REPORTS NOW THAN WHEN THE REPORTS WERE PREPARED BY TYPEWRITER.

AT FIRST OUR CARD PUNCH OPERATORS HAD A DIFFICULT TIME PUNCHING THE DATA BECAUSE THEY PUNCHED ONLY PART OF THE DATA CONTAINED ON THE LAB TEST CARD. THE LAB MANS FORMS HAVE BEEN REVISED SO THAT THE ELECTRONIC PORTION IS IN A BLOCK BY ITSELF ON THE FORM AND, THEREFORE, IS EASIER TO FIND. WE FEEL THE UPDATING OF THIS LAB WORK FORM HAS HELPED TO ORGANIZE LAB PROCEDURES IN THIS AREA.

SEVEN CARDS ARE REQUIRED IN MAKING UP THE SOIL REPORT FORM THAT EACH OF YOU HAVE. TEN CARDS ARE NEEDED FOR THE AGGREGATE REPORT.

THE HISTORY THAT IS BEING BUILT UP IS ON THE TESTS SHOWN ON THESE FORMS.

THESE TWO REPORTS ARE RUN DAILY OR HOURLY AS THE WORK COMES IN TO THE COMPUTER SECTION.

TO DATE WE HAVE APPROXIMATELY 18,000 CARDS ON AGGREGATE TESTS AND 6,000 CARDS ON SOILS TESTS.

No. 18

BOTH LIST AND SEARCH WERE COMPLETED THIS YEAR.

SEARCH IS AN ANALYTICAL RESEARCH PROGRAM USED TO SEARCH AND TABULATE ANY PARTICULAR SOIL OR AGGREGATE TESTS THAT CORRESPOND TO A DESIRED VALUE OR A MULTITUDE OF VALUES REQUESTED BY THE USER.

THIS PROGRAM MAY ALSO BE USED FOR A STRAIGHT TABULATION OF ANY OR ALL SOILS OR AGGREGATE REPORTS. EIGHT TESTS PER SHEET.

IT USES THE SAME INPUT CARDS AS THE LIST PROGRAM AND, IN ADDITION, MASTER CARDS ARE USED TO ESTABLISH THE DESIRED CONTROL VALUES. A HIGH-LOW-OR EQUAL (- B +) OPTION IS GIVEN TO MOST VALUES EXCEPT SIEVE SIZES WHERE A HIGH AND LOW RANGE IS USED FOR CONTROL.

THE PROGRAM MUST MEET ALL OF THE SEARCH CONDITIONS IMPOSED BEFORE IT WILL PRINT OUT ANY RESULTS.

THE 1-1/2 INCH, NOS. 4, 10 AND 200 SIEVES HAVE A HIGH-LOW OPTION WHICH ALLOWS FOR A DESIRED RANGE OF SIZES. THE REMAINING SIEVE SIZES HAVE ONLY THE ABILITY FOR AN EQUAL CONDITION.

BY COMPARING R VALUE (RESISTANCE VALUE) (R VALUE IS USED TO DETERMINE THE THICKNESS OF COVER AGGREGATE REQUIRED TO PREVENT PLASTIC DEFORMATION OF THE SOIL UNDER IMPOSED WHEEL LOADS.), LL, PI AND PERCENT PASSING 200 WITH SAND EQUIVALENT WE FOUND THE SAND EQUIVALENT NEEDLESSLY HIGH AND WERE ABLE TO REDUCE IT FROM 35 TO 30.
WERE ABLE TO REDUCE IT FROM 35 TO 30.

OTHER COMPARISONS WHICH CAN BE MADE ARE R VALUE VERSUS T-99 DENSITY, SE FINENESS MODULUS VERSUS SE DRY, WEAR TEST VERSUS DURABILITY.

AS OUR HISTORY FILE BUILDS UP, SOME OF THE COMPARISONS NOTED ABOVE WILL EITHER SUPPORT OUR PRESENT SPECIFICATION LIMITS OR ELSE CAUSE THEM TO BE REVISED.

SOME OTHER USES FOR THIS DATA ONCE IT IS ON CARDS OR TAPES IS AS FOLLOWS--

1. IT WOULD BE EASY TO KEEP AN INVENTORY OF PIT HISTORY SUCH AS WHEN IT WAS PURCHASED, WHEN IT WAS DISPOSED OF OR EXHAUSTED. A CURRENT FILE OF QUANTITY REMAINING IN THE PIT COULD BE KEPT.

2. UPON RETURNING TO A PIT AFTER SEVERAL YEARS NON-USE, THE FILES COULD BE CHECKED AND PERHAPS ELIMINATE MUCH RETEST WORK.

3. OUR MATERIALS PEOPLE ARE REQUESTING A LISTING OF TEST RESULTS BY SEQUENTIAL PIT SITE ALONG EACH HIGHWAY ROUTE SYSTEM.

THERE ARE TWO PRIME BENEFITS TO THESE PROGRAMS AT THE PRESENT TIME AND THEY ARE--

1. THE TEST REPORT DATA IS KEYPUNCHED DIRECTLY FROM LAB TEST CARDS AND THE LAB TEST REPORTS ARE COMPUTER PRINTED.

2. THE SEARCH PROGRAM HAS THE ABILITY TO COMPARE RESULTS OF ALL PREVIOUS TESTS WHICH MAY SHOW TRENDS.

Charles H. Williams

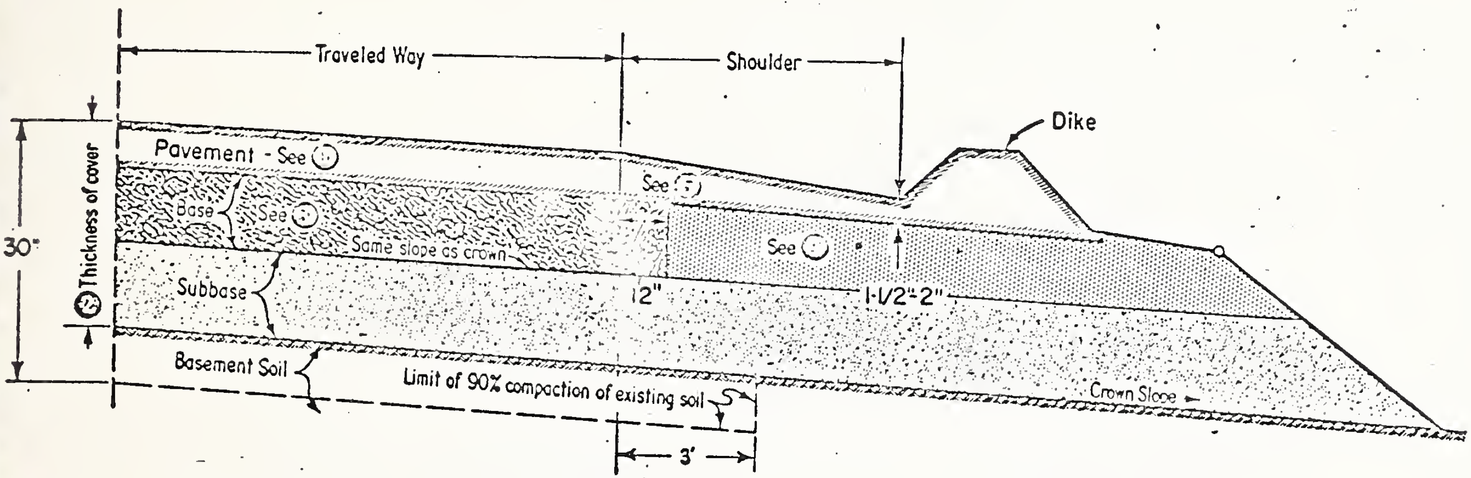
No. 18

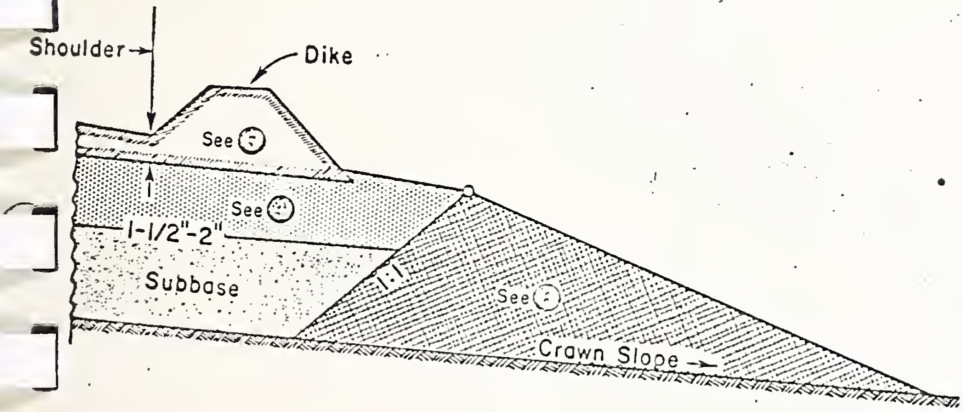
AGGREGATE SEARCH FOR SIEVE NO.200 0-10,SE MFG ABOVE 40,LA

AGGREGATE REPO

LAB CONTROL NO.	AG 66-01-0000	AG 66-01- 2	AG 66-01- 29	
PROJECT				
LOCATION	SW1/4SW1/4		NENE	
DEPTH			75FT	
FIELD SAMPLE NO.	1		P510	
SOURCE NO.	123-45-678	35-10-0085	35-08-0007	
TYPE DEPOSIT	IGNEOUS	LEDGE ROCK		
GRADATION PCT PASS				
3 IN		79.8	35.5	
2 IN	75.2	36.1	34.7	
1 1/2 IN	72.5	13.1	33.7	
1 IN	71.2	4.6	28.5	
3/4 IN	68.6	3.2	20.7	
1/2 IN	66.7	2.5	11.9	
3/8 IN	65.5	2.1	8.1	
NO. 4	61.7	1.7	3.6	
NO. 8				
NO. 10	57.1	1.0	1.4	
NO. 20				
NO. 40	37.8	.6	.7	
NO. 80				
NO. 100		.3	.5	
NO. 200	9.5	.2	.4	
PLASTICITY INDEX NAT	10		NP	
PLASTICITY INDEX MFG	6	NP		
LIQUID LIMIT NAT	27		NV	
LIQUID LIMIT MFG	22	NP		
SAND EQUIVALENT NAT	42		50	
SAND EQUIVALENT MFG	50	49	62	
SE AS RECD MOIST	35			
SE LAB MFG CURED	40			
DURABILITY COARSE	43	49	70	
DURABILITY FINE	55	47	60	
SPECIFIC GRAV CSE	2.76	.	.	.
SPECIFIC GRAV LE CHL	2.69	2.62	2.68	.
IMMER CMP PCT RET	80			
ASPHALT STRIP PCT	ABOVE95	BELOW95		
SULF SND PCT LOSS	5		3	
LA ABRAS PCT LOSS	25	30	18	
VOL. SWELL PCT	0.4	.	.	.
GRANULAR COMP PCF	132	.		
UNIT WEIGHT PCF	137			
AASHO CLASSIF				
DESCRIPTION				
DESIGN R VALUE	62			
SUPPORT VALUE	3.0	.	.	.
STRUCTURAL NO.	5.75	.	.	.
GRAVEL EQUIV (IN)	8			
EQUIVALENCY (IN)				

STRUCTURAL ELEMENTS OF FLEXIBLE PAVEMENTS





TYPICAL DEPTHS RELATED TO BASE QUALITY AND TRAFFIC INDEX							
YPE OF ASE	DEPTH OF PAVEMENT (inches)						
	TI 4.0-4.9	TI 5.0-5.9	TI 6.0-6.9	TI 7.0-8.9	TI 9.0-10.4	TI 10.5-10.9	TI 11.0 +
CTB	—	—	—	3	4	5	6
Value	1½	2	2½	3½	4	—	—
Value	2	2½	3	4	—	—	—
72 R Value	2½	3"	3½	—	—	—	—

① BITUMINOUS PAVEMENT REQUIREMENTS

6" maximum; 1/2" minimum
4" generally used on treated bases

② THICKNESS OF COVER

Use design chart for thickness of pavement, base and subbase, or total cover.

③ BASE THICKNESS REQUIREMENTS

6" minimum when TI is < 8 and > 6.5
8" minimum when TI is 8 or more and < 10
10" minimum when TI is 10 or more
4" minimum when TI is < 6.5 Applies only to Class "C" cement treated base and untreated bases

④ SHOULDER BASE

Use base material or high quality subbase

⑤ SHOULDER DESIGN

Except for all paved 2 lane roads, shoulder design is based on 1% of EWL but not less than a TI of 4.5 or more than a TI of 7.5

⑥ FLAT FILL SLOPE DESIGN

Use embankment material in this area when slopes are flatter than 2:1 and subsurface drainage problems are not anticipated.